Creating Wildfire-Resilient Communities

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Abstract

This chapter examines factors associated with climate change and other evolving technological and societal changes behind the upward trend in the number, scope, severity, and human health and safety, economic, and environmental impacts and costs of large-scale wildfire events. The chapter describes these factors and looks at how they have collectively contributed to an altered wildfire risk landscape and describes how they have increased vulnerabilities and potential consequences for global societies. The chapter employs the state of California as a case study with focus on the unprecedented 2017–2020 wildfire season, which was notable for numerous large-scale wildfires that devastated communities in the northern and southern parts of the state. The case study illuminates some of the more significant impacts of these interrelated climate, technological, and societal change factors in California's large-scale wildfires over those 3 years, examining the role

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they played in escalating wildfire risk to communities and providing examples of various impacts and challenges. The study also identifies significant lessons learned from California's large-scale wildfires during that time period. Lastly, the chapter outlines and describes how to develop a model comprehensive large-scale wildfire community resilience strategy that:

- Can be customized for use by multiple communities in a region
- Engages key public and private sector and nonprofit stakeholders to mitigate existing and emerging large-scale wildfire risks
- Identifies priority large-scale wildfire resilience research, policy, and capabilities gaps that require inclusion in the strategy
- Can be implemented on a continuous basis through collaborative multi-stakeholder actions and shared investments

Keywords

Climate change · Large-scale wildfires · Community resilience · Risk mitigation · Infrastructure interdependences · Public-private collaboration · Holistic resilience strategy

1 Introduction

One of most problematic manifestations of climate change is how it is altering the wildfire risk landscape with serious, adverse effects on societies worldwide. Seasonal wildfires have always occurred in regions where there is low rainfall and high average temperatures with periodic drought conditions resulting in easily combustible ecosystems. Over the last two decades, however, there has been a notable increase in wildfire frequency, intensity, scope, and community health, economic, and environmental impacts with greatly escalating costs. Such *large-scale* wildfires have resulted in long-term deleterious effects on the vitality and societal well-being of communities and regions in many areas of the world. The term "large-scale" is an apt descriptor of wildfires that can devastate multiple communities and impact large portions of a state (or nation) during a single fire season. At present, there is no agreed terminology or methodology to delineate wildfires as to their magnitude or strength, as in earthquakes, hurricanes, and tornadoes (Tedim et al. 2018). Hundreds of these large-scale wildfire events have occurred on nearly every continent since 2000. Some of the most extreme have been in Portugal in 2003 and 2005; Spain and Greece in 2005; Greece, Italy, and the USA in 2007; Australia in 2009; the USA in 2013; Canada and Chile in 2016; Portugal, Chile, and Canada in 2017; the USA in 2017–2020; Brazil and South Korea in 2019; the UK in 2018–2019; and Australia in 2019–2020 (USGCRP 2017; Wikipedia 2020a).

At the same time, climate change-related factors have combined with accelerating technological and societal changes to make communities and the broader regions where they are located increasingly more vulnerable to damage and disruption from

large-scale wildfires. This is notwithstanding that many nations in Europe and Asia, along with the USA, Canada, Australia, and New Zealand, have adopted disaster resilience as a priority national mission. Communities in these countries are striving, mostly independently and with limited financial and other resources, to assess their level of risk, build on existing disaster management capabilities, and develop and operationalize improved preparedness, response, recovery, and mitigation plans, tools, and other capabilities.

Unfortunately, key gaps remain in understanding the interrelated drivers behind the changing wildfire risk landscape and, consequently, what is required in an era of converging climate, technological, and societal changes to develop and execute an effective strategy that over time can significantly improve community wildfire resilience capacities. The first step is to look at these global change factors to illuminate how they contribute to gaps and shortfalls in wildfire resilience research, policy, and capabilities. The second step is to determine what needs to be accomplished to create large-scale community wildfire resilience. Given there is no agreed definition of community resilience, in this context, it is described using a synthesis of various definitions used by different disciplines as "the ongoing capacity of the community to understand its public health and safety, economic, and environmental risks; develop and implement capabilities necessary to prevent, withstand, and mitigate the diverse impacts of an event; recover and restore the community to a state of self-sufficiency, vitality, and well-being; and use lessons learned to improve resilience for the next adverse event" (Chandra et al. 2011; National Research Council 2010; NIST 2020; Scalingi 2012).

2 Change-Related Wildfire Risk Factors

2.1 Climate Change

The trend to hotter, dryer conditions around the world over the last decade has been instrumental in elevating wildfire risk. Rising global temperatures, extensive long-term drought, and periodic heat waves in many regions of the world have directly contributed to catastrophic wildfire events, with the largest temperature increases occurring over the last 14 years. According to the National Oceanic and Atmospheric Administration (NOAA) data, recorded high temperatures were reported across parts of central Europe, Asia, Australia, southern Africa, Madagascar, New Zealand, North America, and eastern South America. Since 1901, the average surface temperature across the USA rose at an average rate of 0.14 °F per decade. NOAA analysis notes that the USA has warmed faster than the rest of the world and that some regions in the USA (the West and Alaska) have experienced more warming than other areas of the USA. Worldwide, the 5 years from 2015 to 2019 were the five warmest years in the 1880–2019 time period (Fig. 1). NOAA reported that February 2020 marked the end to one of the warmest winters on record worldwide, second only to the 2016 season (NOAA 2020a), and April 2020 set the record for the highest average temperatures for that month.

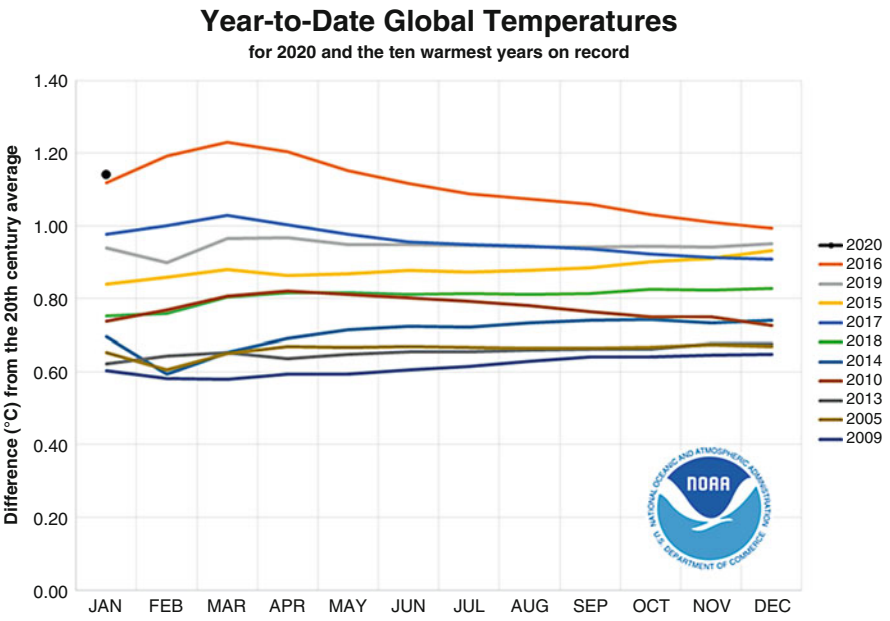

Fig. 1 Year-to-date global temperatures

At the same time over the last 20 years, these above-normal temperatures have combined with below-normal precipitation to produce prolonged drought conditions in many areas of the world. In the USA, for example, there have been droughts affecting over half of the country in 2000, 2002, 2006, and 2012–2017. This last drought impacted nearly two-thirds of the USA, making it the second only to the famous Dust Bowl drought, which affected more than 60% of the USA at its height in 1934 (NOAA 2020b; NIDIS 2020). A recent quantitative study that compared soil moisture data with historical records from tree rings found that most of the US West since 2000 has been, and likely remains, in a "megadrought" (described as a severe drought affecting a broad geographic area for a prolonged period) (Stahle 2020). Prolonged drought at the community and regional levels has been a difficult hazard to address, because it is an evolving, not an immediate, threat and not one that local and state officials take into account in determining wildfire risk and disaster planning. Rather, potential impacts from drought are approached as primarily a water management issue – demand versus supply. Focus is on water use, conservation policies, and regulatory constraints on water usage. Decision-making on policy options is complicated by competing needs of growing metropolitan regions, agricultural users, and environmental interests. Little if any thought is given to how drought-related water management policies can contribute to the incidence and severity of large-scale wildfires.

2.2 Technological Changes Influencing Large-Scale Wildfire Risk

Rising world temperatures over the last two decades have been accompanied by ever-accelerating technological advances that have considerable direct and indirect impacts on societal resilience. Of particular importance are innovations in electronics, computing, and other digital technologies that have created unprecedented levels of interconnectivity from the global to the community levels and changed the way people interact and conduct their daily lives on any number of levels. These technologies and flood of applications and ongoing innovations have provided enormous benefits, enhancing the provision of every conceivable type of information and access to key goods and services that enable improved community health and prosperity. These technologies have had a direct positive impact on individual and community health and disaster resilience, in the latter instance providing tools for alert and warning, detection and monitoring, risk and damage assessments, situational awareness, and information-sharing.

Infrastructure Interdependencies-Related Vulnerabilities. At the same time, these technical innovations have created vulnerabilities that in major disasters such as large-scale wildfires can disrupt or devastate the interconnected critical infrastructures on which communities rely for essential services. The operational reliability and availability of products and services of these critical infrastructures are at the heart of community resilience. They include electric and gas utilities; communications, transportation, and healthcare providers and facilities; fuel producers and distributors; safety, emergency, and other government services; and financial institutions, food/agriculture, and industrial production facilities. The interdependent physical and cyber networks, systems, and key assets that constitute these infrastructures can be directly affected by flames, heat, toxic smoke, or water and chemicals from fire suppression actions, causing service disruptions. The interdependencies among them, which often exist at multiple levels of increasing complexity, leave them vulnerable to indirect and unexpected impacts (Petit et al. 2015). Many of these critical infrastructure assets are often co-located, increasing the extent of both direct and indirect impacts. For example, in large-scale wildfires, damage to power transmission and distribution systems and communications assets can lead to prolonged outages affecting other essential services and impeding effective wildfire response actions, which include alert and warning and timely evacuations. In many regions, large-scale wildfires can impact road and rail transportation systems, impeding emergency vehicles and affecting regional supply chains. Wildfires can disrupt water systems necessary for firefighting, threaten fuel pipelines, and cause evacuations of hospitals. Moreover, restoration of these interdependent services may be prolonged and require large, long-term investments.

Unique Risk Challenges Posed by Energy Grids and Public Safety Power Shutoffs (PSPSs). The electric power infrastructure is unique in that it is both subject to wildfire risk and can pose a direct threat to other interdependent infrastructures and communities it serves. Sparks from downed transmission and distribution power lines, equipment malfunction, or component failure have been implicated in starting some of the most destructive wildfires, in Southern California in 2007, Northern

California in 2015, and in both parts of the state during the 2017 and 2018 fire seasons. These electric power technology-caused accidents have incentivized power companies in high temperature and/or high wind conditions to resort to protective power shutoffs to large numbers of communities. This practice has resulted in millions of residential and commercial customers, including critical infrastructures and other essential service providers, experiencing power outages for hours to days at a time. PSPSs, as they are called, have been aggressively implemented in California by the state's major power providers since the 2018 wildfire season. The practice has elicited widespread concern because it has adversely affected people, including particularly at-risk individuals, critical infrastructures, and businesses, causing significant economic losses and health impacts (Lesser and Feinstein 2020; New York Energy Week 2018).

Creating New Wildfire Risks with Smart Technologies. A related technological trend exacerbating risk from large-scale wildfires and other major natural and man-made hazards is the development of ever-more innovative "smart" technologies and applications and creation of "Smart Cities" in many regions of the world. Smart Cities use the Internet, sensors, actuators, and other technology to connect components and analyze, control, and move large amounts of information across and among broad areas, connecting government agencies, infrastructures and other critical services, businesses, community services, and people (Scalingi 2019). In the last 5 years, there has been a growing number of these Smart Cities emerging around the world. Large cities and many smaller communities across Europe, Asia, the USA, and Australia are adopting smart technologies to offer a growing range of services, including water/wastewater and traffic management, operation of intelligent energy grids, law enforcement and emergency response support, and provision of public information. A worrisome concern of this growing interconnectedness of, and reliance on, smart technologies is the greatly increased potential in large-scale wildfires for cascading failures of these interdependent, diverse networks and systems. Along with direct fire-related damage to buildings and infrastructures, cascading impacts can incapacitate a community or region for a prolonged period and greatly extend restoration timelines for essential services.

Social Media Technologies and Wildfire Risk Perceptions. A last technological factor that has influenced wildfire risk is the development of increasingly sophisticated social media capabilities, which both help and hinder large-scale wildfire resilience. On the positive side, these technologies enable disaster response practitioners, businesses, and other service providers to disseminate in real time public information on outages, evacuations, and other emergency guidance. These tools can also provide critical situational awareness information from both citizens and response personnel. At the same time, these same capabilities can be used to sway public emotions through broadcasting graphic scenes of unfolding wildfire events and provide erroneous or unsubstantiated information that increases fear and stress and may lead to hasty political decisions that exacerbate impacts from the event.

2.3 Societal Changes

Societal changes encompass a diverse range of trends that together are elevating large-scale wildfire risks.

Expansion of the Wildland-Urban Interface. The past two decades has witnessed significant change as to where and how individuals live and the communities in which they reside. Globally, there has been an ongoing expansion of populations in metropolitan areas outward into undeveloped wilderness areas with development and extension of supporting interdependent critical infrastructures, residential housing, and commercial services. This particularly is the case along coastal regions. These so-called wildland-urban interface areas host numerous species of animal and plant life, many of them unique and/or endangered (Readfearn 2020). The expansion of wildland-urban interface areas has been a significant trend in many parts of the world since 2000, including Argentina, Australia, Spain, France, South Africa, and particularly the USA (Radeloff et al. 2018; Suess 2020; Wikipedia 2020b). As part of this trend, there has been a population migration into rural and undeveloped areas to take advantage of their hospitable climates, outdoor recreational potential, and low-cost, country living environment. Communities in these regions lack sufficient staff and financial resources to devote to wildfire prevention, preparedness, and mitigation actions. At the same time, many of these wildland-urban interface areas are historically prone to wildfires either from man-made causes or lightning strikes. Some of these areas are in mountainous or hilly regions that have stretches of forests with dense undergrowth that has accumulated over the years. Other areas, such as the Australian Bush, are uncultivated regions of small trees, low shrubs, and grasslands. In many instances, wildfires in these areas are not easily accessible to firefighters and be of such scope and ferocity that they take days to weeks to contain, requiring mutual assistance from neighboring regions or states and, in extreme cases, other nations.

Toxic Emission Health Impacts: By-Product of Wildland-Urban Interface Wildfires. One of the least understood risks from large-scale wildfires is the short- and long-term health effects from wildfire toxic emissions. Such emissions result in "particulate matter" – fine and coarse particles resulting from the combined burning of vegetation, structures and contents of homes (plastics and other carcinogenic substances from furniture, cleaning and paint supplies, etc.), vehicles, and hazardous chemicals and materials produced or stored by commercial and industrial facilities. Along with particulate matter, wildfire smoke includes gases, such as greenhouse gases (carbon dioxide, methane, nitrous oxide), photochemically reactive compounds (e.g., carbon monoxide), non-methane volatile organic carbon, and nitrogen oxides (CDPH 2019; Huber 2018). This mix of toxic emissions is an immediate hazard to firefighters and emergency services personnel and to communities in the fire's vicinity. Depending on weather conditions and wind patterns, smoke can smother a region affected by a large-scale wildfire for days to weeks, extending to affect communities hundreds of miles away. Smoke from 2019 regional wildfires in California and Oregon extended into Washington State, casting a dense pall over the Seattle-Tacoma area that lasted for days. The 2019–2020 wildfires in Australia at

their peak dropped air quality to hazardous levels over much of the country (Australian bushfires 2020). Individuals exposed to toxic smoke may suffer respiratory, neurological, and cardiological symptoms that require hospitalization and can affect long-term lung function (Wettstein et al. 2018). Particulate matter in the smoke can cause inflammation of the airways, chest pain, coughing, wheezing, and shortness of breath, even in healthy individuals. Particularly affected are children, individuals with underlying health conditions, the disabled, and elderly (CDPH 2019; Stone et al. 2019). In addition to human health issues, in both California and Australia, large-scale wildfire smoke has contaminated citrus in orchards and grapes in extensive vineyards. Moreover, because of incomplete combustion, the chemicals that make up the particles and gases remain in the environment after the fire has been extinguished. This poses a significant hazard to cleanup and restoration service personnel and residents returning to burned areas. It also leads to contamination of soils and groundwater, degrading the future investment potential of the residential and commercial areas affected. Adding to these environmental hazards is contamination by chemical aerial fire retardants dropped over burning areas during firefighting activities.

Diversity and Fragmentation of Wildfire Decision-Making. One of the most problematic issues is the plethora of cross-sector and discipline organizations, interest groups, jurisdictions, and special districts that have formal roles or a "stake" in developing and executing a large-scale wildfire resilience strategy. These stakeholders have different interests and may have strongly diverging views on risk and resilience needs and priorities. They include numerous government agencies from the national to community levels, some with statutory or other mandated authorities that may be overlapping or conflicting, and many other public/private sector and nonprofit organizations and associations with missions or vested interests in wildfire prevention, protection, response, recovery, and mitigation. These "key players" include public and nonprofit entities with responsibilities for emergency management, emergency services, law enforcement, public health and healthcare, mass care and voluntary assistance, community planning, environmental management, forest management, animal control, and air quality and monitoring. Also included are elected and appointed officials; local governance councils and community groups; critical infrastructure owners and operators across all sectors; schools, universities, and other academic institutions; large businesses and business associations; older adult and childcare facilities; and other special interest organizations and advocacy groups that focus on health and safety, the economy, and environment. A complicating factor is that large-scale wildfires are regional disaster events. They do not respect jurisdictional boundaries and may affect more than one county or other political subdivision of a state, multiple towns and small communities, and parkland and other undeveloped areas that may be under state or national purview. Large-scale wildfires also can transcend national borders with direct physical impacts on communities located either side or through disrupting essential services and supply chains. Finally, although localities in wildland-urban interface areas may have their own disaster plans of various levels of proficiency, they may lack effective methods of emergency communications and have limited response

capabilities. While these localities may come together in a unified command structure for large-scale wildfire response and mutual assistance purposes, coordination can be hampered by conflicting priorities and procedures, incompatible communications systems, and competition for scarce personnel, equipment, and other resources.

Political Factors and Related Policy Issues Influencing Wildfire Risk. Generating multi-stakeholder collaboration and consensus on risk and resilience actions is difficult enough but may face daunting obstacles where politics, social, and cultural forces come into play. This is particularly problematical in addressing large-scale wildfires, because the vast majority of necessary resilience improvement actions require multi-stakeholder collaboration and cost-sharing. Another challenge is that stakeholders energized by a recent wildfire event may take initial steps in identifying needed improvement actions but may be deterred from moving forward to operationalize them because it appears "too hard" and/or there is no government or private sector entity stepping up to take ownership. A major issue often is "who pays" for a particular resilience improvement activity or project. This is particularly the case where there are overlapping jurisdictional or organizational authorities, ideological differences, and disagreements over the type, approach, and cost of solutions that should be pursued. Contentious potential actions can include undertaking more aggressive forest and vegetation maintenance practices – e.g., managed burns; selective logging; creation of firebreaks; upgrading, replacing, or removing critical infrastructure assets; hardening residential and commercial buildings to make them more fire resistant; and adopting and particularly, enforcing policies and regulations that direct homeowners and businesses to create defensible space around their properties, remove dead trees, and replace flammable vegetation with fire-resistant landscaping. Especially controversial issues are whether to designate areas most vulnerable to wildfires as off-limits to further residential or commercial development or to prohibit residents from rebuilding homes in high-risk areas that have been impacted by wildfires. While it is tempting to downplay or put aside these and other political issues as too difficult to tackle, addressing them is necessary to make progress in building community resilience and address growing large-scale wildfire risks.

Behavioral Factors Influencing Wildfire Risk. Gauging the risk of wildfire events, as in the case of any hazard risk assessment, is both a quantitative and qualitative process.

- *Implications for Organizations*. There are an increasing number of proprietary and commercial asset management, wildfire models, and other risk assessment tools that critical infrastructures and larger businesses can use to examine potential wildfire impacts to critical assets and services, potential liability issues, mitigation options, and respective costs. Organizations can also turn to studies by universities and other research institutions, analyzing climate change trends and the potential impact of large-scale wildfires on communities and critical infrastructures. These largely data-driven tools and studies, augmented by subjective judgments, inform organizational security, operational continuity, and

mitigation needs. In the end, however, it is at the senior leadership level that organizations will rate the risks to operations and services and determine resilience priorities and mitigation investments. More often than not, senior leaders, particularly in the private sector, will underplay the risks to avoid spending on mitigation actions, to improve the company's bottom line. A further complicating factor is that these tools and studies rarely address wildfire impacts associated with infrastructure interdependencies. Many larger private sector organizations and local agencies have a rudimentary understanding of how critical infrastructures and other essential services are dependent on each other and of high-level potential impacts. However, they lack the necessary assessment tools and data on operational and critical assets to assess interdependencies-related impacts beyond the most superficial levels (Brashear et al. 2015). Although there are various commercially available critical asset and risk assessment software systems available, private sector-produced interdependencies analysis tools are not yet available for critical infrastructure or local government users. Nationally developed tools have not been made available for these users for data security reasons. Consequently, interdependencies modeling and assessment remains largely the purview of research institutions and national agencies. Looking at small- and medium-sized commercial and community organizations that comprise the backbone of a typical locality, most of these lack even informal risk assessments. These entities commonly take a reactive approach, dealing with the emergency when it happens, and turn to local fire and law enforcement for alert and warning and disaster response.

- *Implications for Communities.* Assessing community risk, and particularly multi-community regional risk, is far more problematical. It requires a "whole community" approach to assessing health and safety, economic, and environmental risks. This means taking into account the resident populations, including at-risk and ethnic groups and the homeless, the entire range of interdependent critical infrastructures and the essential public and private sector services serving the geographic area where the community is located, and other, often intangible, factors that determine overall community well-being. Although there are hazard assessment approaches community planners and emergency managers can use, these rely on processes that are largely subjective and are based on input from local officials with limited, if any, broader stakeholder participation. The data provided are more best guesses, extrapolating from damages with which they are familiar from past disasters or from hypothetical scenarios used in training exercises. Moreover, as noted above, community officials do not have access to the proprietary information from risk assessments of their supporting infrastructures and key businesses, let alone from smaller service providers and businesses that do not produce risk assessments (Brashear and Scalingi 2015). Smaller communities, particularly in more rural areas, lack the staff, expertise, or financial resources to undertake a wildfire risk assessment. A further constraint is the natural, human tendency to put on the shelf the lessons learned from past significant disasters and focus on the hazard of the moment. This combined with turnover of personnel quickly degrades institutional knowledge on past

wildfire impacts and demonstrated preparedness, response, and recovery shortfalls.

Lastly, given the increase in the number of and level of destruction from large-scale wildfires over the last several years, communities in wildfire-prone regions must be ready to deal with *multi-disaster* scenarios in which large-scale wildfire response is complicated or even undermined by one or more other disasters. Emergency management officials in communities rarely exercise these scenarios, focusing on a single hazard and typically testing plans and procedures to address that hazard. These officials are reluctant to "complicate" scenarios by adding hazards that they perceive would be beyond their control (and which local plans may not address). A good example is a major earthquake where outbreaks of numerous wildfires sparked by downed power lines, broken gas pipelines, or other ignition sources would immeasurably add to the damage to buildings and infrastructure caused by the earthquake and pose an immense array of additional response and recovery challenges. A second example is a large-scale wildfire in a region populated by several small communities during a global pandemic, such as the COVID-19 pandemic, where populations are observing government-issued directives for stay-at-home, social distancing, and quarantines, and area hospitals and other healthcare services are already at capacity or overwhelmed. Such a scenario would greatly complicate evacuations and mass sheltering. Individuals would be reluctant to leave their homes and go to a shelter in a wildfire for fear of virus exposure, leading to potential high mortality rates. At the same time, it would put an insupportable strain on the provision and operation of firefighting mutual assistance, mass care support, and healthcare and discourage assistance from voluntary aid organizations.

Psychosocial Impacts of Large-Scale Wildfires on Communities and Individuals. The psychosocial impact of disasters on individuals has long been acknowledged and is an area of significant research. Such effects on individuals can include changes in attitude, stress, fear, depression, and an increase in substance abuse and incidence of suicide (Pfefferbaum et al. 2007). There is currently a wealth of resources available online addressing these impacts looking at different types of disasters, including a few on wildfires. Over the last few years, there has been particular focus on the psychosocial effects on communities and different citizen constituencies, including at-risk individuals, and to indirectly affected family members, friends, social groups, small businesses, and the well-being of the whole community (Leon 2004; Reifels et al. 2013). Regarding at-risk groups, in recent large-scale wildfires, particularly older adults number disproportionately among the victims. Moreover, older adults in catastrophic disasters such as large-scale wildfires can suffer a wider range of impacts, including trauma. About 80% of them have at least one chronic health condition, and many require support from caregivers, either at home or in an adult care facility, and medications and special equipment or supplies. Lessons learned from past disasters show that many healthy older adults may refuse to leave their homes even when their lives are at risk (Stiefel et al. 2014). To have a sense of well-being, people also need to feel their communities are safe. Consequently, if they live in communities perceived as vulnerable to wildfires and/or

have experienced wildfire events themselves, residents and businesses may opt to relocate elsewhere when commercial investment in the region is seen as undesirable. A decrease in the value of homes after a wildfire, increasing insurance rates, and the need to undertake costly mitigation measures (hardening or relocating critical assets) are additional incentives to relocate to less risky environments (Barrett 2018).

3 Case Study of the Changing Large-Scale Wildfire Risk Landscape and the Implications for Community Resilience: California 2017–2020 Wildfires

California offers a useful example to examine how climate, technological, and societal changes have combined to significantly increase wildfire risk to communities. The state is the most populous US state with almost 40 million people, making it larger than most countries. California has a large, diverse multiethnic population that includes more than 100 officially recognized Indian tribes. Geographically, California has mountain ranges, deserts, alpine tundra, extensive forests, oak savannas, and rugged coastlines with diverse micro-climates, vegetation, and animal life, including many endangered species. The state has more than 230 locations designated as wilderness areas covering more than 99,823,000 acres and wide swathes of wildland-urban interface areas that are in regions designated as high fire severity zones (Suess 2020; Wikipedia 2020b). In the sprawling metropolitan regions of the San Francisco Bay Area and fanning out around Los Angeles, San Diego, and Sacramento, there are growing pockets of urbanization stretching from Northern through Southern California along the coast and inland, as people migrate into unincorporated and wilderness areas vulnerable to wildfires. These areas have become dotted with growing communities, including many small cities. These communities are often heavily populated with older adults, many of them original residents, as well as retirees seeking a pleasant and lower-cost living environment with good recreational opportunities. They are being joined by millennials, who, for the same reasons, are willing to undertake lengthy commutes to jobs in metropolitan areas. Many of these communities have homes and commercial buildings that were built three or more decades ago and which have not been upgraded to withstand wildfires. Residents and businesses either lack the financial means or the inclination to take on landscaping mitigation measures, such as creating defensible space around their properties through cutting back or removing flammable vegetation; dead trees and shrubs; unused or decaying structures, such as barns and sheds; and woodpiles or other combustible materials. Many individuals with roots in farming and ranching want to preserve the rural environment despite the high-wildfire risk. In addition, many communities in less accessible areas lack adequate road systems necessary for expeditious evacuation of their growing populations. Wildland-urban interface communities are served by aging electric power distribution and transmission lines and equipment and cell phone towers, many of them in remote areas and particularly vulnerable to the state's hot, dry offshore winds. Called Diablo winds in Northern California and Santa Ana winds in the southern part of the state, these winds

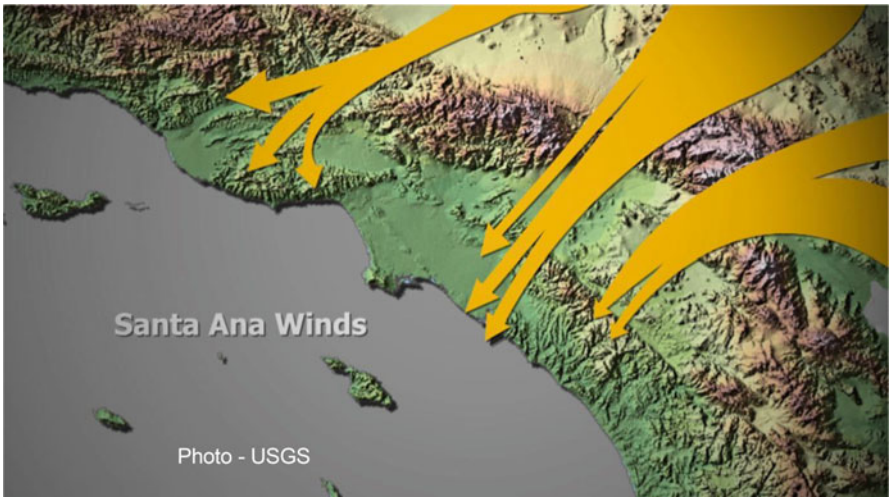

Fig. 2 Santa Ana wind flows in Southern California

commonly occur in the fall through winter, but now with climate change can occur at any time. They can reach hurricane strength with gusts as high as 80 miles an hour in the mountains and mountain passes, channeling across the state's deserts down through coastal regions and valleys, where they can rapidly whip a small fire into a major conflagration that can devastate an entire region. These winds can spark fires by downing power lines and equipment and fan flames from campfires, negligently disposed cigarettes, a backfiring vehicle, arson, or a lightning strike (Cal Fire 2018) (Fig. 2).

The Drought Factor. California, as noted previously, has been among those regions of the world that in recent years have been experiencing more rapid temperature rises and droughts that exceed the overall global average. The state experienced increasing drought conditions that officially started in December 2011 and continued to build over the next 3 years. Drought conditions reached their highest level by the middle of 2014, affecting nearly 60 percent of the state. The response, spearheaded by then Governor Jerry Brown, centered on statewide-mandated substantial residential, commercial, and agricultural water use cuts by localities and water districts. There were significant monetary penalties levied on users for exceeding stringent conservation limits. The result was a wide number of homes and businesses throughout the state "went brown," turning off spigots and irrigation, and letting trees, landscaping, orchards, and farmland die out. In many cases, owners took no steps to remove the dead trees and vegetation after much-needed winter rainstorms replenished water reservoirs and the state conservation measures were suspended. Although the state declared the official end of the multi-year drought in 2017, hotter and drier than historically normal conditions continued to persist (NIDIS 2020) (Fig. 3).

Fig. 3 California battles deadly wildfires in the north and south. (Photo NBC News)

2017–2020 Fire Season. Dead and stressed trees and vegetation in communities and undeveloped areas combined with rising summer temperatures to fuel devastating wildfires in both the northern and southern parts of the state over the 2017–2020 time period. According to the California Department of Forestry and Fire Protection (Cal Fire), in 2017, about 1,500,000 acres burned, nearly double the previous year. During the month of October, eight counties in Northern California experienced large-scale wildfires, resulting in at least 23 fatalities, 245,000 acres burned, and over 8,700 structures destroyed. These fires were followed in December by five more large-scale wildfires in the southern part of the state, burning more than a thousand homes and buildings. Among these latest fires, the Thomas Fire was the largest wildfire ever recorded in California up to that time, a record lasting until the next year. The 2018 season, exacerbated by a summer marked by a period of prolonged three-digit daily high temperatures and parched vegetation and forests still recovering from the 2011–2017 drought, was precedent-setting with more than 7,500 fires charring an area of over 1,670,000 acres, the largest area of burned acreage recorded in a fire season (Cal Fire 2018). Large-scale wildfires began in the middle of July continuing into August, chiefly in Northern California, leading to a national disaster declaration on August 4. Among these fires were the Carr and Mendocino Complex Fires, which burned more than 459,000 acres, with the latter becoming the largest fire event in the state's history and costing an estimated $15 billion. Then in late autumn, Santa Ana winds contributed to conditions already primed for further wildfires to cause another occurrence of large-scale destructive fires across the state, including two of the largest that erupted at virtually the same time in different

regions. The Hill and Woolsey Fires impacting the counties of Los Angeles and Ventura began on November 8, just after the start of what became the state's deadliest wildfire on record, the Camp Fire in Butte County in Northern California. The Camp Fire ultimately killed 86 people, destroyed 13,972 residences, 528 commercial structures, and 4,293 other buildings.

The 2019 fire season was less severe than 2018, according to the National Interagency Fire Center (NIFC), both in numbers of wildfires and acres burned. The most destructive wildfires included two in late October, the Kincade Fire in Sonoma County, burning about 78,000 acres, and the Getty Fire in Los Angeles, which was driven by strong Santa Ana winds. The following month witnessed the Maria Fire in Ventura County that burned 10,000 acres and the Ranch Fire, which burned another 2,500 acres (Insurance Information Institute 2019; Cal Fire 2018).

The trends of ever hotter summer temperatures and a longer, more destructive wildfire season continued in 2020. By mid-August, major conflagrations, including "complex" fires comprised of multiple wildfire events, had erupted across the state, in many instances sparked by widespread intensive lightning strikes and exacerbated by heat waves with triple digit temperatures. Among the most destructive of these events were the SCU Lightning Complex and CZU Lightning Complex fires, which devastating portions of several Bay Area and adjacent counties. As of the end of September, with at least a month of the fire season remaining, more than 8,000 fires across the state had scorched close to an estimated record 4 million acres with a number of wildfire events not yet contained and high heat conditions continuing (Cal Fire 2020).

Apart from the 2020 fire season, the overall economic cost of the wildfires just for the 2017–2019 fire seasons was huge. According to estimates by NOAA, the combined overall direct estimated costs for damage and destruction of buildings, infrastructure, and firefighting for those 3 years were more than $90 billion (NOAA 2020c; Insurance Information Institute 2019). But these estimates failed to capture uninsured and other indirect costs of the 2017–2019 wildfires. Not covered were the longer-term costs of impacts on human physical and mental health, from environmental degradation and associated remediation efforts, infrastructure service and business disruptions, smoke contamination affecting wine and citrus production, reduced air and water quality, wildlife casualties, habitat destruction and restoration, management of soil erosion and sediment buildup, mitigation of flood damages from burned areas, and other collateral damages. These costs are difficult to calculate because they were incurred by local, state, and national agencies and private entities (Barrett 2018). An AccuWeather report estimated that the total damage and economic loss from both direct and indirect wildfire impacts over this period was in fact many times greater. The 2019 costs alone were estimated at close to $80 billion, with a whopping estimated $400 billion in 2018 and $85 billion in 2017, totaling a remarkable $565 billion over the three annual fire seasons (Roach 2019).

Lessons Learned for Large-Scale Wildfire Resilience from the California Experience. Although there had been considerable focus since 2012 on building disaster resilience capabilities at the state level and in the larger metropolitan areas, much of the focus has been on earthquakes and floods, with earthquakes getting the most

attention. Consequently, before the 2017 wildfire season began, conventional wisdom at the state and local levels was that California's communities were relatively well-prepared for hazards they routinely faced, which included wildfires. This assumption was undermined by the growing ferocity, extent, and sheer number of the large-scale wildfires beginning in 2017. The wildfires demonstrated a wide range of challenges and gaps across the community resilience mission-space (St. John and Kohli 2017; San Diego County 2019; Palomino 2018). These shortfalls were documented in after-action reports by the California Office of Emergency Services and affected counties and highlighted in many media accounts (Cal OES 2018; Sonoma County 2018; San Diego County 2019; Smith, 2019; Palomino 2018).

Shortfalls identified include:

- *Lack of risk assessment tools that can better gauge the risks to communities and particularly the interdependent critical infrastructures that support them.*
- *Need for improved methods and tools to provide reliable, timely, and coordinated situational awareness* on the scope, spread, character, and impacts of the wildfires. Challenges for communities to overcome included impediments to communications and cross-sector information-sharing and limited staff with expertise in integrating, analyzing, and displaying disaster impact data and in acquiring essential data from key response agencies and interdependent critical infrastructures.
- *Uncoordinated alert and warning procedures and capabilities with gaps, overlaps, and redundancies*. Part of the problems cited included poor training of emergency responders in pushing out emergency messaging and limited understanding of the alert and warning process and of capabilities that could have been used more effectively to reach residents in fast-moving wildfire conditions.
- *Confusion and lack of understanding during large-scale wildfire response on organizational roles, responsibilities, and authorities.*
- *Scarcity of trained public officials and private sector and nonprofit stakeholders* to assist in large-scale wildfire response. Few key stakeholders had participated in local disaster exercises and lacked familiarity with the Incident Command System (ICS) and local emergency response plans for debris management, commodity points of distribution, volunteer management, etc.
- *Information-sharing and communications challenges* that limited necessary coordination between first responders on the ground and emergency operations centers, as well as among cities, special districts, community organizations, and other key stakeholders on their situation status and resource requirements.
- *Need for ways to raise awareness of and alleviate wildfire toxic smoke health impacts* on first responders and individuals, especially children, older adults, and people with underlying heart, lung, and other health conditions that can be exacerbated by smoke.
- *Procedures for addressing extensive quantities of hazardous debris* from burned residential areas and businesses that require rapid removal for health reasons and methods to mitigate toxic runoff into streambeds and groundwater during the winter rains.
- *Need for improved response and recovery procedures and resources* to address:

  - Evacuations in areas of difficult terrain and limited roads
  - Temporary and particularly longer-term housing needs
  - Identifying other environmental hazards created by the wildfires, e.g., burned areas potentially subject to landslides from winter rains or flash floods and damage to watersheds
  - Providing the public with timely and accurate public information and guidance and avenues for financial and psychological support
  - How to expeditiously undertake restoration of fire damaged or disrupted critical infrastructures
- *Need to improve multi-jurisdiction and cross-sector cooperation and collective decision-making pre-event, during, and post wildfire*. California has relied on a legislation-based state-led hierarchical incident command structure since 1993 to manage coordination and decision-making for multi-jurisdiction disaster preparedness and response, including mutual assistance and allocation of disaster resources. This Standardized Emergency Management System (SEMS) has the California Governor's Office of Emergency Services (Cal OES) situated at the top of the pyramid with counties led by their respective emergency management offices in the middle, grouped in three regional administrative regions (Inland, Coastal, and Southern). The counties function as formal "operational areas" and are the conduit up to the state level for their respective cities, communities, and special districts, which are at the bottom of the pyramid (Cal OES 2020). While the SEMS structure is useful to manage vertical top-down communications and provide guidance during disasters, there can be technical and bottleneck challenges sending information and needs requests up from the local to the state level where mutual assistance and resource decisions are made. Moreover, the SEMS process does not facilitate horizontal multi-jurisdiction/cross-sector coordination among and within communities and counties and their supporting critical infrastructures. These government and private sector organizations in any case are commonly siloed with their own plans and procedures and are largely on their own to deal with fast-moving events like large-scale wildfires.
- *Need to address controversial issues that may grab social media attention pre-event, not during large-scale wildfires*. During and after the wildfires, there was considerable finger-pointing, amplified in social media, by state, local, and federal officials on the causes behind the state's recent catastrophic wildfires with speculation on what and particularly "who" was responsible. There were charges of poor forest management practices and failure to mitigate potential wildfire conditions and of unenlightened community planning that allowed residential and commercial development to spread into wilderness areas. State regulators were blamed for overlooking the poor safety record and system maintenance practices of the Pacific Gas and Electric Company (PG&E), the state's major power provider in Northern California, which were seen as contributing to some of the wildfires.
- *Need for viable solutions to lessen electric power infrastructure-caused wildfire risk*. Although there were different causes identified for several of the fires, downed transmission or distribution lines and other malfunctioning electric

power equipment were implicated in some of the most damaging, including the most deadly and destructive, wildfire, the 2018 Camp Fire located about 80 miles north of Sacramento and serviced by PG&E. Many of those killed were residents of the town of Paradise, either unable to evacuate in time or burned in their vehicles trying to flee the rapidly spreading inferno on the area's limited roadways. The town itself was devastated by the wildfire. There was controversy over to what extent the company should be liable for damages in those cases where its equipment initiated wildfires and how much of that cost should be borne by ratepayers. A key consequence was a declaration of bankruptcy by PG&E on the basis it could face more than $30 billion in liabilities from the 2017 and 2018 wildfires. Another outcome was issuance of a report in June 2019 by the Governor's Office of Planning and Research prepared by a special Commission on Catastrophic Wildfire Cost and Recovery. The report pointed out the expected increase in the number and destructiveness of large-scale wildfires in California and risks associated with the electric power infrastructure, underscored the need to balance the interests of communities in its wildland-urban interface areas with the interests of the state's power utilities, and the need to cooperate and share the costs to mitigate large-scale wildfire risks (Cal OPR 2019). The report provided a series of recommendations, but did not specify how to accomplish this balancing act, which will involve a range of diverse and highly politicized economic, environmental, and cultural issues and require long-term massive investments that would need to be shared by power company shareholders; federal, state, and local governments; private sector investors; ratepayers; and taxpayers. The issuance of the Commission report was followed by adoption of state legislation in July 2019 that created a $21 billion insurance fund with half the cost paid by ratepayers and the other half shared proportionally among California's investor-owned utilities. The legislation also created a Wildfire Safety Advisory Board, to advise the California Public Utilities Commission and to review utilities' implementation of specific safety requirements including a fire mitigation plan, a fire safety committee, and tying executive compensation to development of a utility safety culture (MacWilliams 2020).

- *Need to address impacts from preventative power shutoffs and determine alternative ways to mitigate risk* of wildfire ignition from electric power assets. In the 2019 wildfire season, PG&E and other major power companies resorted to shutting off power in high-wildfire risk areas of the state during high wind conditions. These Public Safety Power Shutoff (PSPS) events caused major controversy. PG&E cut power to millions of its customers nine times during 2019, in some instances for up to a week. San Diego Gas & Electric and Southern California Edison, major power providers in Southern California, did the same to lesser numbers of customers. The power shutoffs disrupted critical services dependent on power, closed businesses, led to spoiled food in grocery stores and household refrigerators, and affected healthcare operations and outpatient services, including dialysis clinics. Estimates of costs of the shutoffs ranged from $850 million to $1.7 billion, mostly in the PG&E service territory in the northern part of the state (Lesser and Feinstein 2020).

- *Need for wildfire mitigation actions that localities with the general public can undertake*, including:
  - Specific and uniform procedures and guidelines for creating defensible space around homes and businesses through eliminating vegetation and decaying/unused structures and clearing space between neighboring homes. These procedures should include ways to raise awareness of the risks if they are not followed and also ways to promote a collaborative, community-wide commitment to work together on landscape mitigation activities. The guidelines should identify low water trees and plants that resist heat and flag plants that are highly flammable for potential removal.
  - Incorporating fire-resistant design features and materials in buildings, creating fuel breaks, and developing post-wildfire mitigation actions to quickly take measures to limit erosion, potential flooding, and habitat damage.
  - Stakeholder-agreed ways to encourage compliance and enforce the above if seen necessary.
- Ways to expeditiously restore critical infrastructure assets from roads and power lines to sewers and watersheds and to assist in the recovery of key businesses, including the tourist industry.

4 Crafting and Implementing a Large-Scale Wildfire Resilience Strategy to Address the Changing Risk Landscape

Considering the factors influencing wildfire risk and lessons learned from large-scale wildfires in California, it is clear that individual communities will not be able to tackle most of these needs on their own. Many require multi-stakeholder collaboration and, in the case of policy issues, state or national leadership and cooperation. Therefore, what is required is a multi-community, or regional resilience strategy for large-scale wildfires that looks holistically at resilience across all its component mission areas: prevention, protection, preparedness, response, recovery, and pre-/post-event mitigation. The strategy should:

- Not be developed in isolation from existing all-hazards jurisdictional and organizational disaster management, continuity, and resilience plans and resources. Rather, it should be designed to leverage and augment these plans and resources with specific needs and corresponding policies, procedures, and capabilities relevant to large-scale wildfires.
- Be developed with input and buy-in *from onset to completion* from the broad public-private sector and nonprofit stakeholder entities previously noted. This is important to ensure the strategy takes into account the interests and expertise of these stakeholders from the beginning and retains their support through implementation and beyond.
- Identify strategic goals, major focus areas, priority needs, and stakeholder-validated improvement actions.

- Include an implementation plan that designates leads and partner agencies and organizations for each activity or project, along with a realistic and flexible timetable for completion, how each potentially will be funded, and staff resources required. The implementation plan should also describe a sustainable process for continuous wildfire resilience improvement that is adequately resourced through multi-stakeholder sharing of monetary and in-kind costs.
- Designed such that it can be tailored for use by any single community or multiple communities that could be collectively impacted in a regional large-scale wildfire event.

Following are general guidelines for developing the strategy and its component elements that can readily be customized to accommodate different localities, states, and nations.

4.1 Development Process

Leadership. Ideally, the strategy development should be jointly spearheaded by one or more senior local government and key businesses leaders as a public-private sector initiative. This will help greatly in participant outreach, engagement, and retention in strategy development and implementation.

Participants. These should include representatives from all key agencies and organizations that have authorities, roles, missions, and vested interests in wildfire resilience from the local to national levels and cross-sector. This whole community constituency encompasses agencies and organizations responsible for public health/healthcare, including behavioral healthcare programs, emergency management, community planning, and business continuity; environmental, agricultural, and forest management issues; fire prevention and response; law enforcement; mass-care, community service groups, and social service nonprofits serving at-risk individuals; ethnic and faith-based groups; businesses and business associations; and schools, and other academic institutions. The process also should include elected officials. (Note: the number of participants in this "umbrella group" may range from several dozen to more than 200, depending on the geographic scope of the initiative. This umbrella group will provide much of the strategy input and final validation. Participants will "self-select" themselves based on their organizational or individual interest in wildfire resilience to be part of a much smaller group that will work closely with facilitators to produce the strategy.)

Collaborative Structure. The development process can use an already established jurisdictional or regional disaster coordination structure or create a new organizational structure expressly for strategy development purposes. An example of an established coordination structure is California's SEMS, which has the added benefit of being the official mechanism for state- to local-level coordination.

Collection of Information and Other Data for the Strategy. Common tools used are scenario-based workshops and exercises, targeted work groups, interviews, surveys, and community meetings.

Facilitation. Ideally will be provided by one or more seasoned, impartial professionals with expertise in resilience and who are skilled in deconflicting and coordinating cross-sector interests and "leading from behind." This can be an officially appointed chief resilience officer, a position which is becoming common in larger localities, a contractor, or a government or industry practitioner with experience in facilitating large, diverse groups to achieve consensus outcomes.

Strategy Scope, Format, and Major Focus Areas. The strategy, as noted, should cover the broad resilience mission-space addressing the changing risk landscape and lessons learned from recent large-scale wildfires and identify needs for research, policies, and capabilities. Because many of these needs, which number in the dozens, fall into two or more of the resilience mission areas, it is useful to categorize them into broad focus areas. Fortunately, there is a template of basic resilience focus areas that already exists and is readily adaptable for a large-scale wildfire resilience strategy. This template was developed in response to lessons learned from Hurricane Katrina, which devastated the New Orleans region with significant loss of life and extensive damages in August of 2005. Those findings formed the basis of a *Regional Disaster Resilience Guide* produced in 2006 by a national cross-sector task force convened by The Infrastructure Security Partnership, a national association representing the engineering and build environment communities. An updated second edition of the *Guide* incorporating findings from subsequent disasters, exercises, and research was published in 2011 (Scalingi 2012).

The original set of resilience focus areas and several dozen capabilities in the *Guide* over the last 14 years has been customized and expanded by a wide range of national governments, states, localities, and nonprofit organizations for use in all-hazards community resilience planning and capability building. It has been tailored so far to pandemics, earthquakes, and floods and more broadly to community resilience and health resilience for use in guides and software tools (PNWER 2010; Chandra et al. 2011; NIST 2020). The following focus area template offers a ready-made framework that can be customized and expanded with wildfire-specific needs highlighted in this chapter to address the changing risk landscape and lessons learned from the 2017–2020 California wildfire seasons and from other wildfire events, as seen in Fig. 4.

Using the Focus Area Template. The 14 focus areas are designed to provide a simple, functional, and straightforward format to organize dozens of diverse needs and potential actions in logical categories. In the strategy, each of the focus areas will have a large number of identified needs paired with respective actions (projects and activities) to address that particular shortfall. When the strategy is completed, all 14 areas will have a list of corresponding needs with actions. These needs with their actions may be grouped under each of the focus areas into short-term (low-cost/1 year), medium-term (18 months to 2 years), and longer-term (multi-year) subcategories.

Below are examples using *five* of the 14 focus areas in Fig. 2 and identifying just one or two of the needs previously cited in this chapter under each focus area with a corresponding action to illustrate how the template would be used for strategy development.

Fig. 4 Disaster resilience focus areas (Scalingi 2010). (Adapted for large-scale wildfires)

Examples:

Focus Area: Multi-stakeholder Collaboration and Cooperation

Need: Identification/delineation and deconfliction of large-scale wildfire roles, responsibilities, and authorities across the resilience mission-space (prevention, protection, preparedness, response, recovery, and mitigation).

Action: Outreach to agencies and organizations with request to describe their respective roles, responsibilities, and authorities, compile the information provided, and convene a meeting of representatives from each of these entities to discuss and validate the findings. Incorporate the agreed results into disaster response and resilience plans, including a brochure for use in training the broader stakeholder constituency in large-scale wildfire response.

Need: Planning and resources to simultaneously respond to two or more major disasters.

Action: Hold a scenario-based multi-stakeholder workshop focusing on a large-scale wildfire occurring with another significant disaster, such as a pandemic, with the goal to identify what types of additional response and recovery resources (staff and equipment) would be needed to address both and also how these resources would be accessed and deployed and what policies, procedures, and constraints, e.g., stay-at-home orders, social distancing, and border closures, could constrain dual disaster response efforts, as well as ways

to circumvent these challenges. Incorporate improvement actions into disaster management plans and test in regional training exercises.

Focus Area: Risk-Based Prevention and Mitigation

Need: Alternative approaches to Public Safety Power Shutoffs as a wildfire response measure.

Action: Examination of costs and timeframes for potential actions to limit energy company reliance on PSPSs in high-wildfire threat conditions. These actions could include setting up microgrids and other decentralized energy resources, rooftop solar power, and storage; expanded use of power generators; longer-term hardening measures for existing utility power infrastructure, e.g., burying power lines where possible; and aggressive forest maintenance to keep trees from encroaching on power lines.

Need: Improved community planning to enable prudent residential and commercial development in high-wildfire hazard areas.

Action: Identify and investigate potential actions that can be undertaken for stakeholder discussion and adoption. These could include retrofit measures to make homes more fire resistant, tax break incentives, creating a fund to assist with retrofitting costs, siting new homes with natural firebreaks and access to evacuation routes, buying burned out properties, instituting zoning restrictions in high-fire-risk areas, etc.

Focus Area: Environmental Issues and Impacts Analysis

Need: Better understanding of environmental hazards from large-scale wildfires and identification of pre- and post-wildfire mitigation actions.

Action: Undertake an analysis of impacts and restoration costs of chemical contamination of groundwater, water bodies including reservoirs, soil, and animal and plant life caused by the burning of hazardous materials commonly present in residential housing and commercial/industrial sites. Develop options to lessen impacts and restoration costs.

Focus Area: Public Health and Healthcare

Need: Better understanding of, and ways to address, the health impacts of hazardous wildfire smoke on first responders and the general public with special focus on at-risk individuals.

Action: Accelerate research on short- and longer-term health effects of wildfire smoke, including chronic smoke exposure, and identify steps to lessen both physical and mental health effects. Potential actions include developing educational materials and messaging for the general public and specifically tailored to at-risk individuals and ethnic groups using social media to convey information on risks, identifying locations for sheltering people from prolonged wildfire smoke, and supplying protective masks and respirators to the public.

Focus Area: Communications and Cross-Sector Information-Sharing

Need: Capabilities for acquiring and sharing multi-stakeholder data and essential information to assess wildfire risks to communities and supporting interdependent critical infrastructures, situational awareness, and decision-making during response and to expedite and prioritize recovery activities.

Action: Adoption of a cross-sector information-sharing network for stakeholder communities of interest with safeguards for sensitive and proprietary information that can enable jurisdictions to use their own communications and other applications to aggregate and overlay various types of data and display potential and actual fire spread and impacts.

4.2 Strategy Implementation Plan and Sustainability Approach

The implementation plan is a compilation of the actions cited in the strategy described in terms of specific projects or activities. These can be prioritized and grouped under the focus areas (or in other ways if desired). The ideal structure for the implementation plan is what typically is used for the improvement plans that accompany exercise after-action reports, which employ a matrix format. The first column lists the focus area, with the second column listing each project or activity. The third column identifies the assigned lead organization(s) and the fourth column the respective partner organizations for each project or activity; the fifth and sixth columns show the projected start dates and estimated completion dates. A final column can be added that specifies the estimated cost of the project or activity and potential sources of support.

The implementation plan should include provisions for maintaining and sustaining the collaborative multi-stakeholder initiative as implementation moves forward. These provisions should describe how the implementation process will be administratively managed and monitored with arrangements for multi-stakeholder oversight and cost-sharing, both financial and in-kind contributions. The implementation plan also should include a process that enables continuous improvement of the strategy by adding needs and actions based on new lessons learned from future large-scale wildfires and exercises. Gaining broad stakeholder agreement on the maintenance/sustainment approach will be the most challenging task in developing and implementing a multi-community wildfire resilience strategy. This is because it takes agencies and organizations out of their traditional mission areas and requires that they direct dollars, staff, and other scarce resources to external activities. Along with budgetary issues, this could raise legal and administrative problems that need to be resolved. However, many of the short-term, low-cost actions necessary for improving large-scale wildfire resilience can be accomplished by organizations that see them as priorities and are willing to use existing budgets and in-kind support to undertake them.

5 Conclusion

The necessity of developing and implementing a holistic, multi-community strategy for large-scale wildfires cannot be overstated. Looking at climate change, the expectation is for a continued escalation of the hotter, drier conditions that have been the trend over more than two decades. Ever-accelerating technological advances will continue to create more systems complexities and interconnectedness

for critical infrastructures and the smart technologies that are providing new and expanded services to communities, and new societal challenges will emerge that have the potential to both help and erode community wildfire resilience. For local governments, partnering with public-private stakeholders to focus on improving their own jurisdictional wildfire plans and capabilities is a positive step but insufficient. The scope of resilience improvement efforts must be regional and multi-community with close state and national involvement, particularly since most of the policy and research needs must be addressed at those higher levels of government. Cultural, political, financial, and other interests can impede this top-down, cross-sector collaboration. However, if there is enlightened government and industry leadership at the local, state, and national levels, the necessary holistic strategy can be developed and implemented to create wildfire-resilient communities.

6 Cross-References

- ▶ Building a Climate-Resilient Murray-Darling Basin in Australia
- ▶ How the Law can Contribute to Protecting Energy Infrastructure from Extreme Weather Events
- ▶ Integrating Climate Change Considerations into Asset Management
- ▶ Public-private Sector Cooperation in Enhancing Resilience
- ▶ Resilient Rural Electrification for the 21st Century
- ▶ Review of Resilient Urban Water Planning Policy and Practice in California

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